CLAIMS

1. An optical integrator, comprising:

an integrally formed plurality of first minute refraction surfaces; and

an integrally formed plurality of second minute refraction surfaces, which are provided closer to a light emission side than the plurality of first minute refraction surfaces so that the plurality of second minute refraction surfaces optically correspond to the plurality of first minute refraction surfaces, wherein

a parameter β satisfies the following conditions:

$|\beta|<0.2$ (where $\beta=(\gamma-1)^3\cdot NA^2/\Delta n^2$), where

a refracting power ratio $\varphi a/\varphi b$ between φa, a refracting power of the first minute refraction surfaces and φb, a refracting power of the second minute refraction surfaces is γ, numerical aperture on the emission side of the optical integrator is NA, and a difference between a refraction index of a medium on a light entrance side of the second minute refraction surfaces and a refraction index of a medium on a light emission side of the second minute refraction surfaces is Δn.

2. The optical integrator according to claim 1, wherein the plurality of first minute refraction surfaces and the plurality of second minute refraction surfaces are formed on the same optical member.

3. The optical integrator according to claim 1, comprising:

a first optical member having the plurality of first minute refraction surfaces; and

a second optical member having the plurality of second minute refraction surfaces arranged on a light emission side of the first optical member.

4. The optical integrator according to any of claims 1 to 3, wherein the plurality of second minute refraction surfaces comprise aspherical surfaces.

5. An optical integrator, comprising in the order from a light entrance side:

a first optical member having an integrally formed plurality of first minute refraction surfaces; and

a second optical member having an integrally formed plurality of second minute refraction surfaces, which are provided to optically correspond to the plurality of first minute refraction surfaces, wherein

a refraction index of an optical material forming the second optical member is set larger than a refraction index of an optical material forming the first optical member.

6. The optical integrator according to claim 5, satisfying the following condition:

$0.05 \leqq nb - na$, where

the refraction index of the optical material forming the first optical member is na, and the refraction index of the optical material forming the second optical member is nb.

7. The optical integrator according to claim 5 or claim 6, which is used for light having a wavelength of 300 nm or less, wherein

the optical material forming the first optical member includes silica glass or fluorite, and wherein

the optical material forming the second optical member includes one material of magnesium oxide, ruby, sapphire, quartz crystal, and silica glass.

8. The optical integrator according to claim 5 or claim 6, which is used for light having a wavelength of 300 nm or less, wherein

the optical material forming the first optical member includes fluorite, and wherein

the optical material forming the second optical member includes silica glass.

9. The optical integrator according to any of claims 1 to 8, wherein

each minute refraction surface is formed spherically or aspherically.

10. The optical integrator according to any of claims 4 to 9, wherein

the aspherical surface is a rotational symmetry

aspherical surface or a rotational asymmetry aspherical surface.

11. The optical integrator according to any of claims 1 to 10, used for

an exposure apparatus, wherein a mask and a photosensitive substrate are relatively moved in relation to a projection optical system along a scanning direction, and thereby a pattern of the mask is projected and exposed on the photosensitive substrate, wherein

an absolute value of the parameter β in terms of a direction optically approximately perpendicular to the scanning direction is set lower than an absolute value of the parameter β in terms of the scanning direction.

12. An illumination optical device for illuminating an irradiated surface, comprising:

the optical integrator according to any of claims 1 to 11.

13. The illumination optical device according to claim 12, wherein the optical integrator forms a light intensity distribution in a given shape in an illumination region.

14. An exposure apparatus, comprising:

the illumination optical device according to claim 12 or claim 13; and

a projection optical system for projecting and exposing a pattern of a mask arranged on the irradiated surface on a photosensitive substrate.

15. The exposure apparatus according to claim 14, wherein

the pattern of the mask is projected and exposed on the photosensitive substrate by relatively moving the mask and the photosensitive substrate in relation to the projection optical system along a scanning direction, and wherein

an absolute value of the parameter β in terms of a direction optically approximately perpendicular to the scanning direction is set lower than an absolute value of the parameter β in terms of the scanning direction.

16. An exposure method, wherein

a mask is illuminated through the illumination optical device according to claim 12 or claim 13, and wherein

an image of a pattern formed on the illuminated mask is projected and exposed on a photosensitive substrate.

17. The exposure method according to claim 16, wherein

the pattern of the mask is projected and exposed on the photosensitive substrate while the mask and the

photosensitive substrate are relatively moved in relation to a projection optical system along a scanning direction, and wherein

an absolute value of the parameter β in terms of a direction optically approximately perpendicular to the scanning direction is set lower than an absolute value of the parameter β in terms of the scanning direction.

18. An exposure apparatus, comprising:

an illumination optical system including an optical integrator; and

a projection optical system for forming a pattern image of a mask on a photosensitive substrate, wherein

the pattern of the mask is projected and exposed on the photosensitive substrate while the mask and the photosensitive substrate are relatively moved in relation to the projection optical system along a scanning direction, wherein

the optical integrator comprises: an integrally formed plurality of first minute refraction surfaces; and an integrally formed plurality of second minute refraction surfaces, which are provided closer to a light emission side than the plurality of first minute refraction surfaces so that the plurality of second minute refraction surfaces optically correspond to the plurality of first minute refraction surfaces, and

wherein

a parameter β satisfies the following conditions:

$|\beta|<0.2$ (where $\beta=(\gamma-1)^3 \cdot NA^2/\Delta n^2$), where

a refracting power ratio $\varphi a/\varphi b$ between φa, a refracting power of the first minute refraction surfaces in terms of a nonscanning direction optically approximately perpendicular to the scanning direction and φb, a refracting power of the second minute refraction surfaces in terms of the nonscanning direction is γ, numerical aperture on the emission side in terms of the nonscanning direction of the optical integrator is NA, and a difference between a refraction index of a medium on a light entrance side of the second minute refraction surfaces and a refraction index of a medium on a light emission side of the second minute refraction surfaces is Δn.